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Timber Utilization and the Potential of Forest Energy in Finland with Reference to the IEA Member Countries

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TIMBER UTILIZATION AND THE POTENTIAL OF FOREST ENERGY IN FINLAND WITH REFERENCE TO THE IEA MEMBER COUNTRIES

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PREFACE

In April, 1978, a number of countries within the International Energy Agency (IEA) decided to sign an Implementing Agreement (IA) for a program of research, development and demonstration on forestry energy. The work is implemented via Programme Groups and Cooperative Projects.

Work within the group for biomass growth and production has resulted in many reports which are being published in this series. The funds for the publication of these reports have been supplied by the Biomass Energy Project of the National Research Council of Canada, the Ontario Ministry of Natural Resources, and the Canadian Forestry Service.

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ABSTRACT

This report, which was initiated by the International Energy Agency (IEA), outlines the utilization and potential of forest energy in Finland and other IEA countries. The possibility of estimating the forest energy resources of these countries on the basis of international forest resource and timber utilization statistics is also examined. The concepts of tree stock and increment characteristics vary greatly in different countries. A better conceptual consistency would improve the estimates of forest energy potential and international comparison.

New methods are urgently needed for better estimating the biomass of the complete tree. As stem volume is the key characteristic in current forest inventories, functions giving the other partr of the tree biomass on the basis of the stem volume should be worked out for different tree species and for different growing conditions.

RÉSUMÉ

Ce rapport, lancé par l'Agence International de l'Énergie, esquisse l'utilisation et le potentiel énergetique de la forêt en Finlande et dans les autres pays de l'AIE. La possibilitiée d'estimer les ressources énergetiques forestières de ces pays par l'utilisation des statistiques internationales concernant la ressource forestière et l'utilisation du bois est également examinée. Mais, les concepts portant sur les caractéristiques de densité et d'accroissement varient fortement entre les différents pays. Une meilleure cohérence conceptuelle améliorerait les estimations du potentiel énergetique forestier et permettrait une meilleure comparaison au niveau international.

Il est donc urgent d'établir de nouvelles méthodes afin d'améliorer l'estimation de la biomasse de l'arbre entier. Comme le volume de la tige est la caractéristique clé des inventaires forestiers, les fonctions donnant les autres parties de la biomasse de l'arbre basée sur le volume de la tige devront être établies selon les espèces et selon les conditions de croissance.

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UTILISATION OF TIMBER AND FOREST ENERGY IN FINLAND

General Conditions for Timber Growth

Finland is located in Northern Europe between the Scandinavian countries and the Soviet Union. It lies across the Arctic Circle between 60° and 70° latitude. The southern part of the country is bounded by the Baltic Sea and its gulfs, with connections to the North Sea and Atlantic Ocean.

Most of the country lies below an altitude of 400 m. The terrain is of low relative relief and is characterized by small hills. There is an abundance of inland lakes and rivers which serve as floatways for transporting timber.

The natural vegetation is essentially boreal coniferous forest with a zone of treeless tundra in the north and small areas of temperate mixed forests in the southwest. In the sub-arctic areas, the climate is relatively warm due to the North Atlantic Drift which brings warm water to the Atlantic coast of the Scandinavian peninsula. Consequently, there are frequent warm air masses from the southwest and west.

Conditions for timber growing, however, are dominated by the coldness of the climate. The mean temperature in the warmest month (July) is between +13° and +17°C, and is between -3° and -14°C in the coldest month (February). The length of the growing season is 120 days in the most northern part of the country and 170 days in southern Finland.

The annual precipitation is 400 mm in the north and 700 mm in the south. Due to the coolness of the climate, there is enough moisture for vegetation. On flat terrain, and also on the northern hills, excessive stagnant water and swamp peat are the worst factors decreasing or impeding forest growth.

The current annual increment of stemwood, over bark, is 1.4 m^3/ha in northern Finland and 4.0 m^3/ha in southern Finland. The potential annual increment for the same areas are 4.0 m/ha and 5.0 to 8.0 m^3/ha.

Finland was an agrarian country up to the end of the 1940's. However, from that time onwards, it very rapidly became industrialized. The proportion of the labour force in agriculture was 40% in 1950 but has decreased to only 12% in 1980.

Small and medium-size farms are typically scattered throughout the country. Income from forestry has been an essential basis for the livelihood of the farming population since the beginning of the nineteenth century; the farming population was ideally situated to provide the forestry labour force, especially during the period of rapid industrialization.

With a scarcity of other natural resources, the development of Finland's national economy has been based on the utilization of the forests. Its dependence on forestry is possibly greater than in any other national economy. Forestry and the wood-processing industries have been, and are still, the most important export industries. Their share of exports by value was 80% in the 1950's and is 45% at the present time.

The Utilization of Timber Before 1950

Annual statistics for timber consumption have been available since 1860. Information concerning commercial timber is relatively reliable, but most of the timber in the agricultural period was cut and consumed by the farming population from their own and state forests and is not, therefore, included in the systematic statistical records. The first study of the consumption of fuel and household timber was carried out in 1927.

According to the statistics, the consumption of timber in 1860 was 16.0 million (M) m^3 (solid measure, stemwood, over bark; the bark proportion was approximately 16%). The population was then 1.7 M. The total consumption of fuelwood was 12.0 M m^3.

In 1900, total consumption was estimated at 26.0 M m^3, fuelwood use was 13.0 M m^3, and the population was 2.7 M. At this time, transport and communication, based on the steam engine, annually consumed 0.8 M m^3 of fuelwood.

The real consumption of timber was obviously much greater than these estimates. Numerous observations, descriptions and early photographs testify that the forests were over-utilized in those areas which were populated in the late nineteenth and early twentieth century. There was a serious shortage of sawlogs and construction timber except in inaccessible areas of virgin forest.

A realistic assumption is that large amounts of fuel and household wood and all the timber consumed for tar extraction and charcoal burning, as well as by shifting cultivation, are not included in the old official statistics. Therefore, the actual drain of timber from the growing stock (the stem volume of the living trees) was much greater than the recorded consumption. Apart from the drain from harvesting, the losses caused by forest fires, diseases and mortality were also much greater than today.

During shifting cultivation, the trees were cut and burned and agricultural crops were grown on the cleared soil which was fertilized by the ash. When fertility began to decrease, cropping was discontinued and natural forest regeneration began. Most of the areas were grazed by cattle during the regeneration period. When the forest was mature enough, the trees were again cut and burned to provide areas for a new crop rotation.

At its greatest extent, shifting cultivation covered 4.0 M ha of land and consumed approximately 5.0 M m^3 of timber per annum. Large, uncontrolled forest fires were often connected with shifting cultivation.

Tar extraction reached its peak at the end of the eighteenth century - the period of wooden ships - when Finland was one of the greatest tar exporters. At that time, tar extraction consumed 10.0 M m^3 of timber per annum. In addition, great amounts of wood were consumed in charcoal production.

On the basis of the probable growing stock and its increment, the drain of stem timber can be estimated at 50.0 M m^3 per annum in the middle of the nineteenth century. The portion of this which was industrial timber, mainly sawlogs, was 2.0%, wood consumed by shifting cultivation and tar and charcoal production was 30.0%, and the share of fuel, household and contruction wood was 40.0%. Mortality and cutting residues left to decay in the forest comprised the remaining portion, a little less than 30.0% (Figure 1). In 1900, the corresponding statistics were 20.0% (industrial wood and 2.4 M m^3 of exported timber), 10.0%, 45.0% and 25.0%, respectively.

During the first and second decades of the twentieth century, the use of wood by shifting cultivation and for tar and charcoal production came to an end, although considerable amounts of charcoal were produced during the First and Second World Wars. During this period, sawmilling increased rapidly and pulping became a major branch of the forest industry. The consumption of industrial timber was 15.0 M m^3 in the 1920's and 19.0 M m^3 in the 1930's.

The annual consumption of fuelwood proper averaged 15.0 M m^3 per annum until 1950. The fuelwood used by industry was 1.5 to 3.0 M m^3 per annum. Although the population and the need for energy increased, water power, coal and oil began to take the role of the most important energy sources. The use of wood residues as a fuel in the forest industry, however, has increased continuously. The total amount of wood material used as fuel was approximately 20.0 M m^3 per annum in 1950.

The consumption of fuelwood proper reached its highest values (21.0 M m^3 per annum) during the years of the Second World War. Domestic energy resources, i.e. wood, peat and water power, covered almost all the needs for primary energy between 1940 and 1945 (Figure 2).

Timber as a Raw Material for Forest Industries and Energy in 1950 to 1980

During the past thirty years of rapid industrialization and great structural changes in society, the drain of stem timber has increased from 50.0 M m^3 per annum to 55.0 M m^3 (Table 1; Figures 3 and 4). Due to the fluctuations in economic conditions and the production of forest industries, the annual drain has also fluctuated greatly. At its maximum in 1963, the drain was 63.0 M m^3 and it reached a minimum of 41.0 M m^3 in 1975 and 1976.

The share of the total drain used by the forest industries increased from 40.0% to 80.0% during this period and its portion of the total consumption of wood rose from 46.0% to 87.0% or from 20.0 to 46.0 M m^3, over bark, per annum.

The annual export of timber was 4.0 M m^3 in 1950, 6.0 M m^3 in 1961 and 0.6 to 2.0 M m^3 during the 1970's. The import of industrial timber started in the second half of the 1960's and amounted to 5.0 to 6.0 M m^3 in the middle of the 1970's and 4.1 M m^3 in 1980.

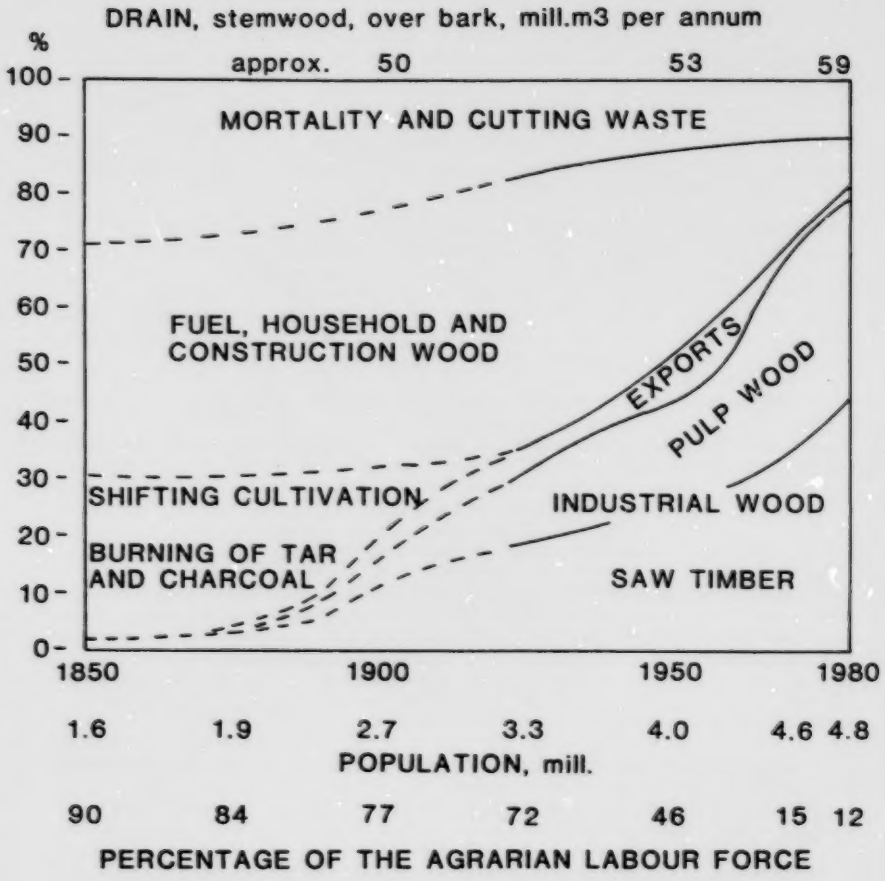


Figure 1. Drain of Stem Timber from Different Uses in Finland

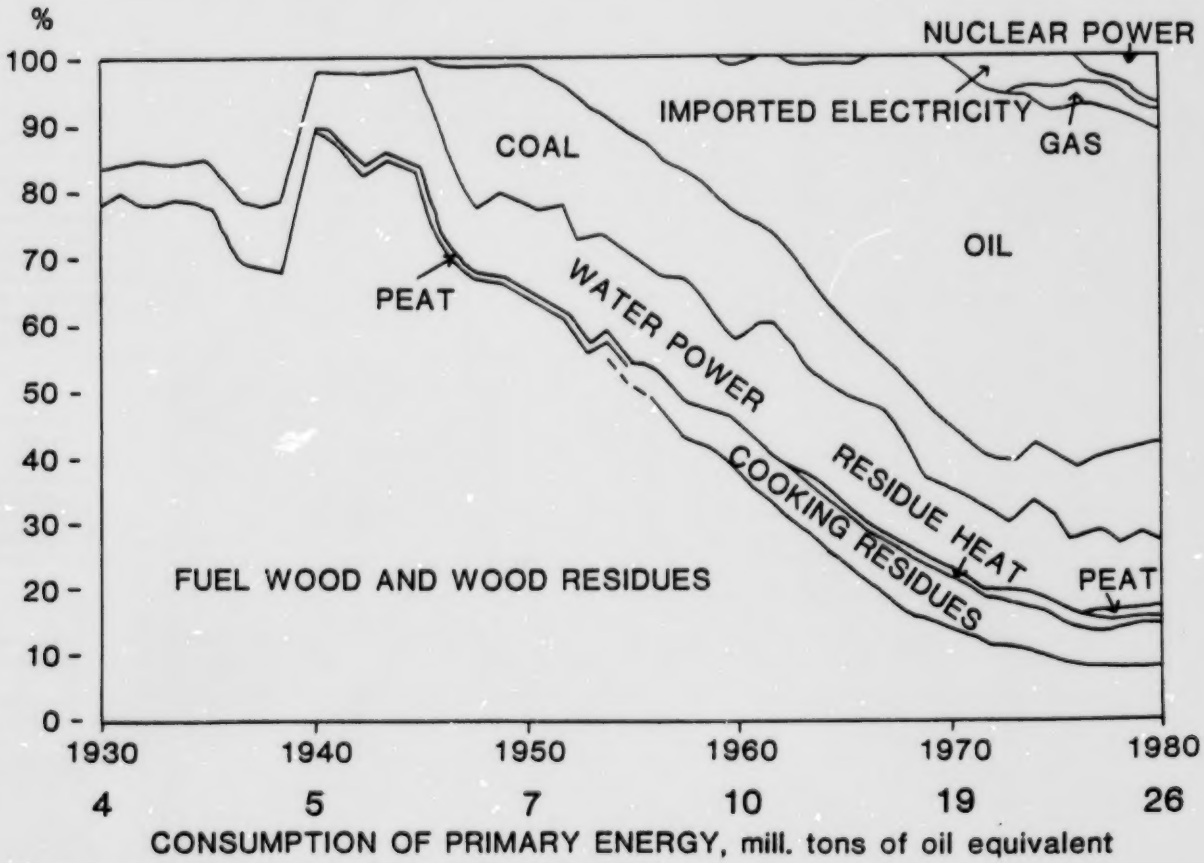


Figure 2. Production of Primary Energy by Sources in Finland

Table 1. Drain of Stemwood, Including Bark, in 1950 and 1970 to 1980

Components of the drain	1950		1970		1971		1972		1973		1974		1975		1976		1977		1978		1979		1980	
	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%
Industrial wood	20.1	40	41.1	70	38.4	70	39.2	72	39.9	73	37.9	73	27.8	69	29.2	72	31.3	73	36.4	77	45.0	79	46.2	79
Exports	4.1	8	1.3	2	1.2	2	0.7	1	0.7	1	0.6	1	0.7	2	0.7	2	1.1	2	0.7	1	1.3	2	2.0	3
Fuelwood																								
industrial	1.9	4	0.1	.	0.1	.	0.1	.	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.
communication	2.3	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Farms and buildings	12.0	24	9.0	16	8.4	16	8.0	15	7.7	14	7.4	14	7.1	17	5.7	14	5.2	12	4.6	10	4.3	8	3.9	7
Total	16.2	32	9.1	16	8.5	16	8.1	15	7.8	14	7.4	14	7.1	17	5.7	14	5.2	12	4.6	10	4.3	8	4.0	7
Other use	3.0	6	0.5	1	0.6	1	0.6	1	0.6	1	0.6	1	0.5	1	0.6	1	0.9	2	0.8	1	0.8	1	0.8	1
Total consumption	43.4	86	52.0	89	48.7	89	48.6	89	49.0	89	46.5	89	36.1	89	36.2	89	38.5	89	42.5	89	51.4	90	53.0	90
Cutting residues	4.7	10	5.5	9	5.1	9	5.0	9	4.8	9	4.3	9	3.4	8	3.3	8	3.9	8	3.7	8	4.5	8	4.6	8
Floating losses	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Total losses	4.9	10	5.5	9	5.1	9	5.0	9	4.8	9	4.3	8	3.4	8	3.3	8	3.3	8	3.7	8	4.6	8	4.6	8
Cutting drain	48.3	96	57.5	98	53.8	98	53.6	98	53.8	98	50.8	98	39.5	97	39.5	97	41.8	97	46.2	97	56.0	98	57.6	98
Mortality	2.0	4	1.2	2	1.2	2	1.2	2	1.2	2	1.2	2	1.2	3	1.2	3	1.2	3	1.2	3	1.2	2	1.2	2
Total drain	50.3	100	58.7	100	55.0	100	54.8	100	55.0	100	52.0	100	40.7	100	40.7	100	43.0	100	47.4	100	57.2	100	58.8	100

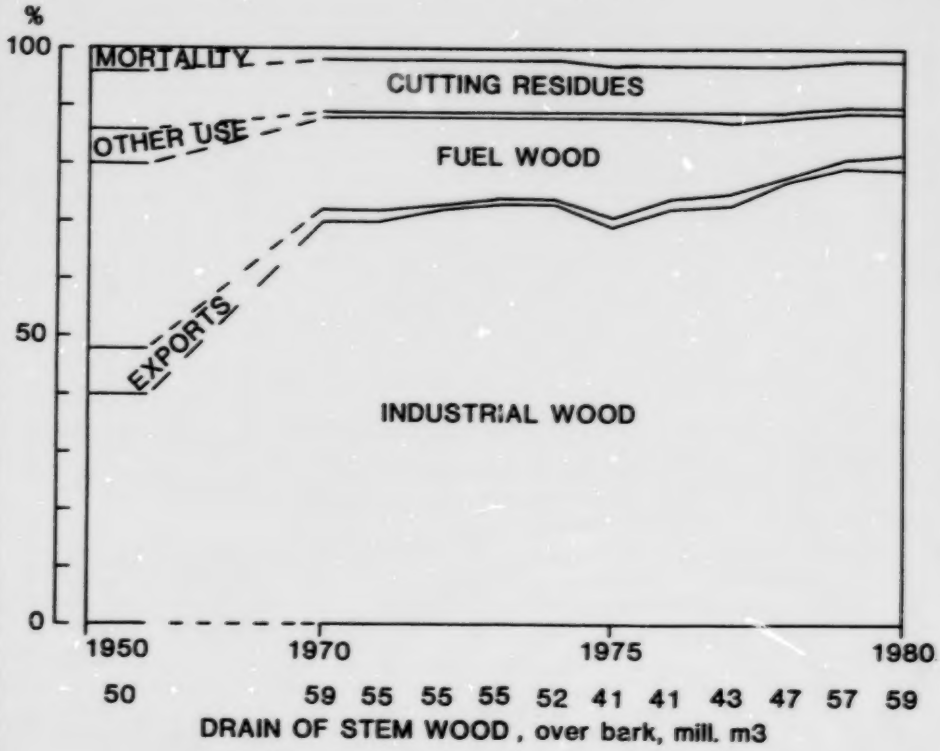
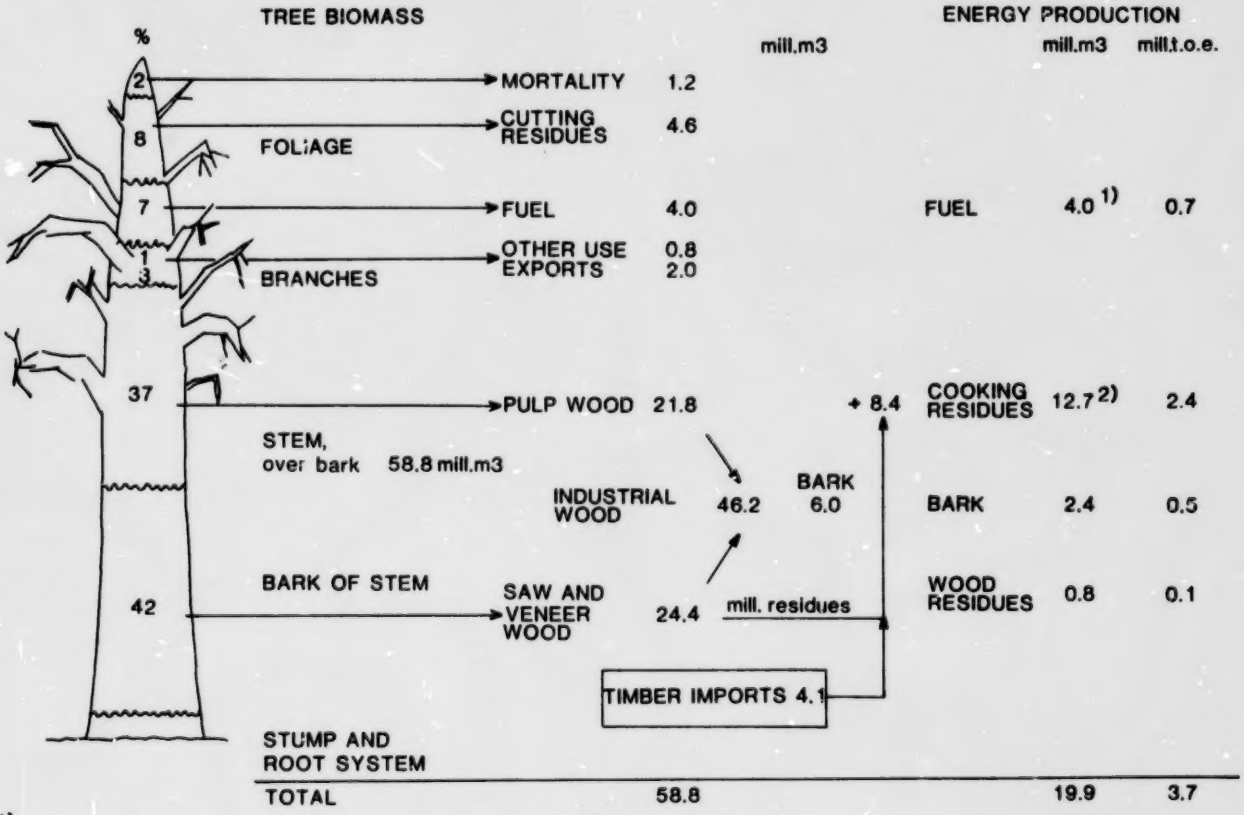


Figure 3. Proportional Drain of Stemwood by Use in Finland in 1950 to 1980



1) Fuel wood consumed is converted into energy by 5.4 m3 of wood = 1 t. o. e.

2) Energy produced by burning cooking residues is converted into wood material by 1 t. o. e. = 5.4 m3 of wood.

Figure 4. Drain and Utilization of Tree Biomass in Finland in 1980

The annual use of wood residues from saw- and veneer mills, as raw material for pulp and chip- and fibreboard, increased from 1.0 M m^3 to 8.0 M m^3 from 1960 to 1980.

As a result of the great changes in wood consumption and the more effective use of timber, the production of the forest industry could increase without a corresponding increase in removals from domestic forests. The production of the primary industries (sawn wood, veneer, chip- and fibreboard, and pulp) increased 2.7 times from 1950 to 1980; the production of paper and paperboard was multiplied by 7.8, consumption of domestic industrial timber by 2.3, consumption of total industrial timber by 2.5, total consumption of domestic timber by 1.2, but the drain increased by only 1.2.

The annual consumption of fuelwood proper decreased from 16.0 M m^3 to 4.0 M m^3 over the same period. On the other hand, the energy produced by the forest industry from wood for cooking and washing residues increased. The amount of wood material used as raw material for energy was 20.0 M m^3 per annum, 35.0 to 40.0% of the total timber consumption. Its energy value was 3.7 M t.o.e. (tons of oil equivalent) in 1980, 14.0% of the total production of primary energy. During these years, domestic energy sources comprised 25.0 to 30.0% of primary energy which was 26.0 M t.o.e. in 1980. The forest industry consumed fuels worth 5.3 M t.o.e. in 1980, of which 57.0% was energy from wood materials.

FOREST ENERGY POTENTIALS IN FINLAND

The Concepts of Forest Biomass

Forest biomass is comprised of trees, shrubs, and other vegetation. The woody component of biomass is of primary importance as an energy resource.

In traditional forest management, the growing stock consists of the volume of tree stems measured and presented in cubic metres (m^3), solid measure, over or under bark. The portion of bark should always be estimated and presented.

In many cases, the growing stock is limited to the volume of merchantable stem or bole, which is the part of the stem of specified quality from stump height to a minimum top diameter. For energy resource purposes, it is also necessary to know available logging residues.

In temperate and boreal zones, the trees are generally characterized by a central stem extending from ground to top. The common target has been to assess the total or merchantable stem. In the tropical and sub-tropical zones, including monsoonal climates, the trees are characterized by a large proportion of branch wood. The branch wood of certain tree species up to a specified diameter may be included in the harvestable volume.

Tree biomass proper comprises the complete tree including stem, branches, foliage, stump and roots. For practical purposes, the roots below a specified minimum diameter are excluded. This part of the complete tree can be called the stump and root system. The height of the stump is specified by local harvesting practice. Branches refer to all limbs and twigs excluding foliage. Foliage is comprised of needles, leaves, buds, flowers and fruit.

The tree above stump means all components of the complete tree except the stump and root system; this is usually the object of estimation of tree biomass for energy production purposes. Biomass measurements are made using units of volume, green weight and dry weight. The final and most important unit of measure should be dry weight. In all but dry weight, the moisture content should be indicated. Weight per unit of volume can be called density; dry weight in kilograms per cubic metre (kg/m^3) is the basic density of wood.

In asessing the energy value of a forest from current forest inventory information, attention should be paid to the specifications of the surveyed area. Important specifications are those which define stem, stump, merchantable stem, cutting residues and merchantable parts of branches.

The growing stock, in most cases the same as the tree stock in traditional resource information, is the volume of stems specified by the inventory. The in-flow to the stock is the annual increment of the growing stock. The out-flow from the stock is drain. Increment during a period of study includes the increment of the trees which have been included in the growing stock since the beginning of the period and of the trees which have grown into the stock during the period.

Drain comes from two sources, mortality and harvesting. Fellings, the volume of stems harvested, is divided into removals comprised of timber assortments, and cutting residues which can be divided into logging residues and silvicultural residues. Residues comprise those parts of stems which do not meet the specifications of timber assortments and those stems which are cut and left in the forest in regeneration areas, tended seedling stands, etc.

The total increment is often called gross increment. Net increment is gross increment minus mortality. The growing stock at the beginning of a period of time is called the initial stock and at the end of the period it is the final stock. Final stock minus initial stock indicates the increase or decrease in the growing stock. An important equation for forest stocking, therefore, is:

initial stock + increment + drain = final stock

These concepts can also be applied to quantified stock and to the stock of complete-trees or trees-above-stump.

A portion of mortality in the form of stems and stumps of coniferous tree species may remain as dead stock in the forest for a number of years in the boreal and temperate zones, and is important as a source of fuel and timber. The dead stock is usually estimated in forest inventories.

Principles for Estimating and Presenting Forest Biomass Characteristics

Complete-tree and tree-above-stump are the object of assessment of tree biomass as an energy source; both are difficult to measure. So far, they have not been included in the traditional forest inventories.

The most advantageous way to start estimates of tree biomass is to take the stem volume, over bark, from stump to top as a key characteristic. Other parts of the complete tree are estimated as functions of the stem volume and other relevant independent characteristics. If the merchantable stem has been the object of an inventory, the "unmerchantable" parts of the stem volume can be estimated.

In order to calculate the dry weight of stems, basic density values are needed. In a study carried out in Finland, the independent variables which explain the tree-to-tree variance of basic density are:

- tree species
- size and form of stem (h = height, d = diameter at breast height, d_6 = diameter at 6 m above ground)
- age of tree
- speed of growth (volume/age)
- climatic region
- genetic factors

Current basic density functions for tree species are based on diameter at breast height, height, age and climatic region.

The average densities of green volume and basic densities for those tree species which comprise almost 100.0% of the growing stock volume in Finland are:

	Green weight		Basic density	
	over bark	under bark	over bark	under bark
	kg/m^3			
Pinus sylvestris, pine	865.0	870.0	405.0	415.0
Picea abies, spruce	810.0	810.0	385.0	385.0
Betula pendula, white birch B. pubescens,	900.0	890.0	495.0	495.0
Alnus incana, alder	840.0	800.0	360.0	360.0
Populus tremula, aspen	840.0	800.0	400.0	400.0

Information concerning the regressions of the parts of complete-tree on the stem quantity, and other possible independent variables, is very preliminary at the present. The proportional values presented in Table 2 are used in Finland.

Table 2. Tree Biomass and Its Energy Potential in Finland

Area of the closed forest: 19.9 M ha; growing stock of stem wood, above stump, over bark: 1598.0 M m^3
Other wooded land: 3.4 M ha; growing stock: 33.0 M m^3
Area outside forest but growing trees: 0.3 M ha; growing stock: 17.0 M m^3

Total stock of living trees 1648.0 M m^3
Stock of dead trees 35.0 M m^3

Stock and its parts	Tree stock and its energy value: M m^3	basic density kg/m^3	dry weight M t.	proportional value	energy[1] value M t.o.e.	Increment and its parts	Tree material flow to the growing stock: M m^3 per annum	dry weight M t.	proportional value	energy[1] value M t.o.e.
Growing stock						Increment				
Coniferous	1351.0	396.0	535.0		250.0	Coniferous	50.7	20.1		9.4
Non-coniferous	297.0	476.0	141.0		55.0	Non-coniferous	14.9	7.1		2.7
Total stemwood	1648.0	410.0	676.0	100.0	305.0	Total stemwood	65.6	27.2	100.0	12.1
Stemwood under bark	1401.0		575.0	85.0	259.0	Stemwood under bark	56.4	23.4	86.0	10.4
Bark of stems	247.0		101.0	15.0	46.0	Bark of stems	9.2	3.8	14.0	1.7
Timber assortments, o.b.	1483.0		608.0	90.0	275.0	Timber assortments, o.b.	60.4	25.0	92.0	11.2
Cutting residues, o.b.	165.0		68.0	10.0	30.0	Cutting residues, o.b.	5.2	2.2	8.0	0.9
Branches, o.b.	379.0		155.0	23.0	70.0	Branches, o.b.	15.1	6/3	23.0	2.8
Foliage	181.0		74.0	11.0	34.0	Foliage	7.2	3.0	11.0	1.3
Stump and root system	379.0		156.0	23.0	70.0	Stump and root system	15.1	6.3	23.0	2.8
Total living biomass	2587.0	410.0	1061.0	157.0	479.0	Total living biomass	103.0	42.8	157.0	19.0
Dead biomass	55.0	410.0	23.0		10.0	Dead biomass	-	-	-	-
Total biomass	2642.0	410.0	1084.0		489.0	Total biomass	103.0	42.8		19.0

[1] Energy value: 1 ton of oil equivalent = 5.4 m^3 of tree material with 20.0% of water content (multiplier for dry weight tree material is 5.2)

In the Finnish National Forest Inventory, the stem volume, over and under bark, from the stump to the top of the tree, is estimated for all trees which have a height of at least 1.3 m above ground. Shrubs are excluded even if their height exceeds 1.3 m.

The stump height is at least 10.0 cm above the ground or at the highest root neck which prevents the cutting of the stem by chain saw. The stump and root system includes roots over 5.0 cm in diameter.

The timber assortment portion of stems is up to the minimum diameter of 6.0 cm, over bark, for a log at least 2.0 m long and at least of pulpwood quality.

The growing stock of complete-trees is supposed to increase by an increment percentage which equals the increment percentage of the stem volume.

In the results of the National Forest Inventory, there are estimates of stem volume, over and under bark, by tree species. Stem volume is divided into timber assortments (saw- and veneer logs and pulpwood) and cutting residues, which consist of stems and parts of stems under timber assortment specifications. Additional information includes the increment of the growing stock volume by tree species and stem volume of those dead trees which comprise wood of usable quality. The drain of the stem volume is estimated by timber utilization studies.

On the basis of the estimates of stem volume and its increment and of the principles described above, tree biomass and its annual increment and energy values in Finland have been calculated in Table 2. The stem volume of living trees is 1,648.0 M m^3, with a dry weight of 676.0 M tons; the stem volume of the annual increment is 65.6 m^3 with a dry weight of 27.2 M tons. The corresponding energy values are 305.0 and 12.1 M t.o.e., with the water content of the tree material assumed to be 20.0%.

The total living biomass of trees is 2,587.0 M m^3, 1,061.0 M tons dry weight and 479.0 M t.o.e. The corresponding estimates for the annual increment of the tree biomass are 103.0 M m^3, 43.8 M tons dry weight and 19.0 M t.o.e. The total tree biomass, including dead trees, is 2,642.0 M m^3, 1,084.0 M tons dry weight and 489.0 M t.o.e.

The biomass of woody shrubs and tree seedlings under the height of 1.3 m is, as an approximate estimate, 6.0 M tons.

Tree Biomass and Its Energy Potential

The energy potential of tree biomass and its annual increment as an in-flow to the biomass stock, as indicated in Table 2, is summarized in Table 3.

The energy of the tree biomass stock (489.0 M t.o.e.) and its annual increment as the in-flow to the stock (19.0 M t.o.e.) can be considered as a renewable store of energy raw material in the event of a national emergency, i.e. if the routes of international trade were blocked. Even then, however, only a major part of stem volume and minor portions of the branches, foliage, and stump and root system can be utilized because of technological restrictions.

Table 3. Energy Potential of Tree Biomass and Its Annual Increment as an Inflow to the Biomass Stock

	Stock		Increment	
	Volume M m^3	Energy[1] M t.o.e.	Volume M m^3	Energy[1] M t.o.e.
Stems under bark	1,401.0	259.0	56.4	10.4
Bark of stems	247.0	46.0	9.2	1.7
Stems over bark	1,648.0	305.0	65.6	12.1
Timber assortments, o.b.	1,483.0	275.0	60.4	11.2
Cutting residues, o.b.	165.0	30.0	5.2	0.9
Branches, o.b.	379.0	70.0	15.1	2.8
Foliage	181.0	34.0	7.2	1.3
Tree above stump	2,208.0	409.0	87.9	16.2
Stump and root system	379.0	70.0	15.1	2.8
Biomass of living trees	2,587.0	479.0	103.0	19.0
Biomass of dead trees	55.0	10.0	--	--
Total tree biomass	2,642.0	489.0	103.0	19.0

[1] Energy value: 1 ton of oil equivalent = 5.4 m^3 of tree material with 20.0% of water content (multiplier for dry weight tree materials is 5.2)

There are also biological factors which restrict increased complete-tree harvesting. Current timber assortments, over bark volume, include approximately 30.0% of the mineral nutrients of the complete-tree stock. Harvesting of small branches, twigs, and foliage may impoverish sites without artifical fertilization, especially in barren conditions, parts of rain forests, etc.

Under the current energy price conditions, timber harvesting losses and the export prices of forest industry products, only the low-quality parts of stem volume and small amounts of the branches, foliage, and stump and root system have practical energy value. Branches and foliage can be harvested only in connection with the harvesting of timber assortments proper.

About 4.0 M m^3, over bark, per annum, of industrial quality stemwood is used as fuel on farms and by heating establishments at the present. This may increase to 5.0 M m^3 in the near future.

It is intended that the use of small-size and low-quality stemwood, which presently remains in the forest as cutting residues, as fuel in heating establishments will be increased. As a result of technological and economic restrictions, however, the use of this tree material may only amount to 1.0 M m^3 per annum by the end of the 1980's.

The forest industries are, and will remain, the most important energy producers using wood as the raw material. The production and use of energy from bark and low-quality tree material in the cooking liquor and in the washing water of pulp and paper mills is an essential part of the production process. In addition to the traditional utilization of wood material as fuel, intensive research and development work is being carried out in the technology for harvesting whole-trees above the stump in initial thinnings and cutting residues after final harvesting. Better quality parts, comprising approximately 80.0% of the total tree material harvested and transported to the mills, can be used for pulping and the rest can be used for fuel. Proportional shares may vary according to the market situation.

The yield from first thinnings by harvesting with the whole-tree chipping method is approximately 25.0% greater than the yield when harvesting only timber assortments proper.

If the drain of stemwood per annum were equal to the increment, the components of the drain during the 1980's could be:

	coniferous	deciduous	total
	(M m^3 per annum, over bark)		
drain	50.7	14.9	65.6
reduction caused by nature reserves and national parks	-1.0	-0.3	-1.3
mortality unused	-1.0	-0.2	-1.2
fellings	48.7	14.4	63.1
logging and silvicultural residues	-2.7	-2.3	-5.0
removal of timber assortments	46.0	12.1	58.1
fuelwood	1.5	3.5	5.0
industrial timber	44.5	8.6	53.1

The additional amount of fuelwood harvested from the current logging and silvicultural residues, branches and foliage could be 1.0 to 2.0 M m^3 per annum in the near future. These estimates are still more or less theoretical because the actual drain will obviously be less than the increment, as it was in the 1970's (Table 1). A realistic forecast of wood-based energy supply in 1990 is:

	M t.o.e.
traditional fuelwood and cutting residues	1.3
cooking liquor, bark and low-quality wood in forest industries	3.0
total	4.3

FOREST ENERGY RESOURCES IN IEA MEMBER COUNTRIES

International Forest Statistics as a Basis for Estimating Forest Energy Resources

Although FAO and other international organizations have collected and published information on forest resources and the utilization of timber for several decades, the current information is neither adequate nor reliable as a basis for estimating forest energy resources. The greatest drawback is that many basic concepts and terms have different meanings in different countries. Besides this, systematic and statistically sound forest inventories have been carried out in only a few countries.

The basic forest resource information should include the areas of land classes where timber is grown. The latest FAO inquiry of European forest resources consists of three classes:

- closed forest or forest land proper capable of timber production
- other wooded land where trees are scattered or growing poorly
- land outside forest and other wooded land, with tree growth

Many countries have comparatively accurate and reliable data only for forest land proper. However, woody material for energy purposes may be abundant on other land classes.

In many cases, there is only accurate data for forests which are exploitable; information on forests which are unexploitable, because of technological, economic and transport conditions, may be lacking or inadequate. A forest which is unexploitable from the point of view of industrial and commercial timber may nevertheless be an important source of fuelwood for the local population.

Information on growing-stock volume proper and its increment is often inadequate. Even in many systematic inventories, only the merchantable or exploitable trees and parts of tree stems are surveyed. Therefore, there is no information at all concerning those parts of the growing stock which are most important as a source of fuelwood.

Information concerning increment may include only the net increment of merchantable growing stock excluding the unmerchantable portions and mortality.

From the point of view of energy resource information, current data are, in most cases, considerable underestimates. As an example, the increment of stemwood, over bark, in European forests (excluding the European parts of the Soviet Union) were estimated to be 470.0 M m^3 per annum in 1970. On the basis of the general information of the growth of trees on different sites and climatic conditions, it can be concluded that the actual increment at the time was at least 550.0 M m^3.

Table 4 illustrates how the increment may vary according to different concepts found in international statistics. The information in the table is based on the results of the Finnish National Forest Inventory and describes the current increment under average Finnish growing conditions. Gross increment is an estimate of the total increment of stem volume. Gross increment should be available for any serious attempt to estimate forest energy resources. Net increment is gross increment minus mortality.

Table 4. Increment of Stem Volume per Hectare on Forest Land (19.7 M ha) in Finland According to the Results of the National Forest Inventory in 1971 to 1976 and Difference Concepts of Increment

	Gross Increment	Net Increment			
		Mortality Percentage			
		2.0	10.0	30.0	50.0
Total stem volume					
over bark	[1] 2.86	[1] 2.80	2.57	2.00	1.43
under bark	[1] 2.46	[1] 2.41	2.21	1.72	1.23
		Logging-residue percentage			
		8.0	10.0	30.0	50.0
Timber assortment Volume					
over bark		[1] 2.58	2.31	1.40	0.72
under bark		[1] 2.22	1.99	1.20	0.62

	Logging-residue percentage				
	0.0	8.0	10.0	30.0	50.0
[2] "Increment of standing volume"					
over bark	1.14	1.05	1.03	0.80	0.57
under bark	0.98	0.90	0.88	0.69	0.49

[1] Estimates for Finnish forestry conditions
[2] "Increment of standing volume" is calculated by dividing the growing stock volume per hectare of each age class by the number of age years. The estimate per forest land area is calculated on the basis of the age-class estimates

The increment of the merchantable growing stock includes only the annual increase of timber assortment volume. In those forests where it is impossible to carry out thinnings because of technical, transport and economic restrictions, the "increment of standing volume" may be used. This exploitable yield is calculated for each tree stand by dividing the current stand volume by the number of years in the age of the stand. The increment of a forest area is the summation of the stand increments. It excludes mortality and the volume of possible thinnings.

If it is supposed that under average Finnish growing conditions, mortality and logging residues are both 30.0%, the increment estimates obtained according to different concepts are as follows:

	m^3/ha	proportional value
gross increment		
over bark	2.86	100
under bark	2.46	86
net increment		
over bark	2.00	70
under bark	1.72	60
merchantable increment		
over bark	1.40	49
under bark	1.20	42
increment of standing volume stem volume		
over bark	1.14	40
under bark	0.98	34
merchantable volume		
over bark	0.80	28
under bark	0.69	24

This example clearly illustrates how misleading increment information can be if it is not known which concept has been applied.

The timber utilization statistics include, in most cases, only the industrial and other commercial timber. The estimates of fuel and household wood consumption are either lacking or they are considerably underestimated. The estimates of mortality and logging residues are often unreliable. This, and inadequate forest resource data, are the principal reasons why the actual and potential production of wood is so often underestimated.

Forest and Forest Energy Resources in IEA Member Countries on the Basis of International Statistics

Information on the forest and forest energy resources are compiled from the latest international statistics available (see references). They may turn out to be out-of-date if compared with the current data of individual countries. Since the conversion factors to calculate the parts of the total biomass from stem volume are very approximate, the values presented in the following tables can only be magnitude-class estimates.

Total land area by the principal land-use classes is presented in Table 5. There is a great variation in forest area per capita. The greatest areas per capita are 15.5 and 4.8 ha in Canada and Finland and the smallest areas are 0.03 and 0.06 ha in the United Kingdom and Belgium. Therefore, the relative importance of forest-energy potential varies greatly between countries.

The area of closed forest divided into operable closed forest in use and in total, and inoperable closed forest, are presented in Table 6. The inoperable closed forest is proportionally greatest in Canada and the United States because of the large virgin forests outside timber production in these countries.

Estimates of growing stock (volume of tree stems) and net annual increment of growing stock (gross increment minus mortality) are presented in Table 7. With respect to the climatic conditions, there is a great unexplainable variation in the estimates of the growing stock and increment from country to country. Many estimates are out of date and smaller than the current actual growing stock and increment because forest resources are increasing in most of the industrialized countries.

On the basis of the mean net annual increment per hectare, it can be concluded that all of the estimates are not based on the same concept. They are often a poor basis for estimating the raw-material potentials for forest industries and fuel. In many countries, the estimate of the increment is obviously smaller than the actual increment.

The recorded removals of timber assortments (Tables 8 and 9) are, in most countries, so much smaller than the estimate of the net increment that the growing stock has increased in 1971-1979 or the amount of logging residues has been very great.

Tentative and very approximate estimates of the total biomass of the growing stock and average annual drain of the biomass are presented in Tables 10 and 11. The intensity of the utilization of forest resources, the percentage of removals against the growing stock and the proportion of the removals of the total biomass of the felled trees, varies much from country to country. Although the information is not very reliable, it is obvious that a considerable amount of tree material is left to decay in the forest.

CONCLUSIONS

Reliable information on the utilization and potential of forest timber and energy resources requires accurate resource inventories and utilization statistics. Greatest inaccuracy in utilization estimates is obviously caused by the poor information on fuel and household wood consumption.

The concepts of the tree-stock and increment characteristics vary greatly in different countries. A better conceptual consistency would improve the estimates of forest energy potential and international comparisons.

New methods are urgently needed for better estimating the biomass of the complete tree. As stem volume is the key characteristic in current forest inventories, functions giving the other parts of the tree biomass on the basis of the stem volume should be worked out for different tree species and for different growing conditions.

The basic characteristics of forest resources, such as the growing-stock volume and especially its increment, are greatly underestimated in many countries.

In the case of an energy crisis, the existing forests are an important source of energy raw material in those countries which do not have sufficient resources of oil and coal. Inadequate information on the current forest resource is a serious obstacle for developing an operable system of methods and equipment to utilize wood as fuel under such circumstances.

Table 5. Land Use in IEA Countries

Country	Closed forest			Other wooded land	Closed forest and other wooded land		Agricultural land	Other land	Land area	
	Total	Per Capita	Of total land		Total	Of total land			Total	Per Capita
	M ha	ha	%	M ha	M ha	%	M ha	M ha	M ha	ha
Finland	19.7	4.80	65.0	3.6	23.3	76.0	3.2	4.0	30.5	6.5
Norway	8.3	2.15	27.0	0.6	8.9	29.0	0.9	21.0	30.8	7.9
Sweden	23.5	2.99	58.0	2.4	26.4	64.0	3.4	11.4	41.1	5.1
Belgium	0.6	0.06	20.0	-	0.6	20.0	1.5	0.9	3.0	3.0
Denmark	0.5	0.09	13.0	-	0.5	12.0	2.9	0.8	4.2	0.8
Germany Fed. Rep.	7.2	0.11	30.0	-	7.2	30.0	13.4	3.7	24.3	0.4
Ireland	0.3	0.09	4.0	-	0.3	4.0	4.8	1.8	6.9	2.3
Italy	6.3	0.11	21.0	1.7	8.0	27.0	17.4	4.0	29.4	0.5
Luxembourg	0.1	0.20	31.0	-	0.1	32.0	0.1	-	0.3	0.8
Netherlands	0.3	0.02	8.0	0.1	0.3	10.0	2.6	0.5	3.4	0.2
United Kingdom	1.6	0.03	7.0	0.3	2.0	8.0	19.0	3.1	24.1	0.4
Austria	3.7	0.49	45.0	-	3.7	45.0	3.8	0.8	8.3	1.1
Switzerland	1.0	0.16	25.0	0.1	1.1	27.0	2.0	0.9	4.0	0.6
Greece	2.5	0.28	19.0	3.2	5.8	44.0	4.3	2.8	12.9	1.5
Spain	14.3	0.28	19.0	4.4	14.1	28.0	20.5	15.4	50.0	1.4
Turkey	8.1	0.19	11.0	12.0	20.1	26.0	27.3	30.1	77.5	2.1
Australia	42.5	3.20	5.0	65.2	107.8	18.0	492.3	161.9	762.0	54.9
Canada	310.1	15.50	34.0	15.4	326.1	35.0	68.0	528.7	922.0	39.6
New Zealand	6.2	2.30	23.0	2.3	8.5	23.0	14.4	4.0	26.9	8.7
United States	202.2	1.50	34.0	94.7	296.9	33.0	430.3	191.8	919.0	4.2
Japan	25.3	0.25	68.0	-	25.3	68.0	5.5	6.4	37.2	0.3

Table 6. Operable Closed Forest Areas in IEA Countries

Country	Closed forest (M ha)			
	Operable closed forest			Total area of closed forest
	In use	Total	Inoperable	
Finland	19.1	19.1	0.6	19.7
Norway	6.8	6.8	1.5	8.3
Sweden	21.7	21.7	1.7	23.5
Belgium	0.6	0.6	-	0.6
Denmark	0.4	0.4	-	0.5
Germany Fed. Rep.	7.1	7.1	0.2	7.2
Ireland	0.3	0.3	-	0.3
Italy	5.3	5.3	1.0	6.3
Luxembourg	0.1	0.1	-	0.1
Netherlands	0.3	0.3	0.1	0.4
United Kingdom	1.6	1.6	-	1.6
Austria	2.8	2.8	0.8	3.7
Switzerland	1.0	1.0	-	1.0
Greece	1.8	1.8	0.7	2.5
Spain	9.3	9.3	5.0	14.3
Turkey	8.1	8.1	-	8.1
Australia	37.9	37.9	4.6	42.5
Canada	163.8	208.4	117.8	326.1
New Zealand	0.9	0.9	5.3	6.3
United States	195.3	205.6	92.6	298.1
Japan	16.9	16.9	8.3	25.2

Table 7. Growing Stock and Annual Increment in Closed Forest

Country	Closed Forest	Growing stock				Net annual increment				
		Total	Per unit area	C	NC	Total	Per unit area	Of growing stock	C	NC
	M ha	M m^3 o.b.	m^3/ha	M m^3 o.b.			m^3/ha/a	%	M m^3 o.b.	
Finland	19.7	1,520.0	77.0	1,254.0	266.0	57.43	2.9	3.8	45.27	12.16
Norway	8.3	563.0	67.0	451.0	112.0	17.18	2.1	3.1	13.41	3.77
Sweden	23.5	2,288.0	97.0	1,966.0	322.0	63.30	2.7	2.8	54.00	9.30
Belgium	0.6	71.0	118.0	40.0	31.0	2,62	4.4	3.7	1.52	1.09
Denmark	0.5	45.0	90.0	22.0	23.0	2.30	4.6	5.1	1.50	0.80
Germany Fed. Rep.	7.2	1,022.0	142.0	722.0	300.0	34.00	4.7	3.4	25.80	8.20
Ireland	0.3	15.0	50.0	13.0	2.0	1.85	6.2	12.3	1.63	0.22
Italy	6.3	286.0	45.0	114.0	172.0	14.02	2.2	4.0	2.60	11.42
Luxembourg	0.1	13.0	130.0	2.0	11.0	0.40	4.0	3.1	0.14	0.26
Netherlands	0.3	20.0	67.0	16.0	4.0	1.26	4.2	0.7	1.00	0.27
United Kingdom	1.6	121.0	76.0	68.0	53.0	5.72	3.6	3.7	4.64	1.07
Austria	3.7	681.0	184.0	580.0	101.0	17.29	4.7	2.5	14.66	2.60
Switzerland	1.0	270.0	270.0	186.0	84.0	5.19	5.2	1.9	3.57	1.62
Greece	2.5	134.0	54.0	79.0	55.0	3.70	1.5	2.8	1.94	1.76
Spain	14.3	436.0	30.0	259.0	177.0	30.03	2.1	6.9	20.72	9.31
Turkey	8.1	836.0	103.0	549.0	287.0	21.89	2.7	2.4	12.39	9.50
Australia	42.5	1,239.0	29.0	109.0	1,130.0	--	--	--	--	--
Canada	310.1	22,170.0	71.0	17,580.0	4,590.0	333.30	1.1	1.5	258.30*	75.00*
New Zealand	6.2	311.0	50.0	196.0	115.0	8.40	1.4	2.7	8.00	0.40
United States	195.3	20,135.0	103.0	12,908.0	7,227.0	614.00	3.1	3.0	348.00	266.00
Japan	25.3	2,186.0	86.0	1,215.0	971.0	71.00	2.8	3.3	39.00	32.00

C = Coniferous tree species
NC = Non-coniferous tree species
* = estimated

Table 8: Average Annual Removals (ub) in 1971-1979 in IEA Countries

Country	Roundwood		Ind. roundwood		Sawlogs + veneerlogs		Pulpwood		Fuelwood	
	C	NC	C	NC	C	NC	C	NC	C	NC
					1000 m^3, ub					
Finland	29,352	9,208	28,221	4,550	14,002	1,333	1,329	3,071	1,129	4,658
Norway	7,760	725	7,590	352	4,062	158	2,948	315	170	373
Sweden	49,943	6,815	48,782	4,954	23,272	445	25,089	4,415	1,161	1,861
Belgium x	1,632	1,204	1,612	932	780	655	456	226	60	271
Denmark	1,099	799	1,075	709	589	531	163	86	24	70
Germany Fed. Rep.	20,437	8,688	19,694	7,523	13,263	3,617	5,239	2,749	743	1,166
Ireland	363	21	360	14	206	14	151	---	31	7
Italy	1,273	5,615	1,060	3,641	710	1,652	57	687	213	2,890
Netherlands	661	334	649	313	107	133	347	315	12	21
United Kingdom	2,398	1,265	2,316	1,134	1,267	893	785	195	82	131
Austria	10,504	2,092	10,193	1,334	7,707	470	1,729	815	310	758
Switzerland	2,835	1,218	2,699	614	2,041	361	588	248	136	604
Greece	665	2,116	357	400	292	255	42	104	309	1,716
Spain	7,445	4,919	6,743	2,688	3,108	824	3,118	1,450	703	2,231
Turkey	11,733	27,177	5,707	1,328	3,738	1,016	1,219	100	6,026	25,848
Australia	2,922	10,617	3,700	9,716	1,984	6,251	865	2,874	---	901
Canada	126,905	12,037	125,759	9,427	88,967	5,109	35,654	4,318	1,146	2,499
New Zealand	8,490	727	8,292	617	5,286	460	2,537	143	198	110
United States	251,074	82,693	248,329	72,059	16,948	33,054	71,601	32,180	2,856	11,333
Japan	22,456	16,422	22,447	14,924	18,897	4,610	2,434	9,744	8	1,500

x Luxembourg included

Table 9: Average Annual Removals in 1971-1979 In Relation To Annual Increment

Country	Net annual increment underbark	Of growing stock, ob	Removals				
			Total	N	NC	Of net annual increment, ob	Of growing stock, ob
	M m^3	%	M m^3 ub			%	
Finland	49.4	3.3	38.6	29.4	9.2	78.0	2.5
Norway	14.8	2.3	8.5	7.8	0.7	57.0	1.5
Sweden	54.4	2.4	56.8	50.0	6.8	104.0	2.5
Belgium	2.8	3.3	2.8[a]	1.6[a]	1.2[a]	88.0[a]	3.3
Denmark	2.1	4.7	1.0	1.1	0.8	90.0	4.2
Germany Fed. Rep.	30.6	3.0	29.1	20.4	8.7	95.0	2.8
Ireland	1.6	10.7	0.4	0.4	-	25.0	2.7
Italy	12.6	4.4	6.9	1.3	5.6	55.0	2.4
Luxembourg	0.4	3.1	-	-	-	-	-
Netherlands	1.1	5.5	1.0	0.7	0.3	91.0	5.0
United Kingdom	5.0	4.1	3.7	2.4	1.3	74.0	3.1
Austria	15.6	2.3	12.6	10.5	2.1	81.0	1.9
Switzerland	4.7	1.7	4.1	2.9	1.2	87.0	1.5
Greece	3.8	2.8	2.8	0.7	2.1	74.0	2.1
Spain	24.6	5.6	12.4	7.5	4.9	50.0	2.8
Turkey	17.8	2.1	38.9	11.7	27.2	219.0	4.7
Australia	16.1	1.3	13.5	2.9	10.6	84.0	1.1
Canada	228.0	1.0	138.9	126.9	12.0	61.0	0.6
New Zealand	8.4	2.7	9.2	8.5	0.7	110.0	3.0
United States	614.0	3.1	333.8	251.1	82.7	54.0	1.7
Japan	71.0[b]	3.3	38.9	22.5	16.4	55.0	1.8

a Luxembourg included
b estimated

Table 10: Total Biomass of Trees Felled in 1971-1980, Per Annum, on the Basis of the Proportional Shares Used for the Finnish Estimates

	Removals	Bark of removals	Harvesting losses	Branches	Foliage	Stump and roots	Total biomass
	M m^3 ub	1000 m^3 ob					M m^3, ob
Finland	38.6	6,333.0	3,860.0	11,233.0	5,365.0	11,233.0	76.6
Norway	8.5	1,394.0	850.0	2,474.0	1,182.0	2,474.0	16.9
Sweden	56.8	9,315.0	5,680.0	16,529.0	7,895.0	16,529.0	112.7
Belgium[x]	2.8	459.0	280.0	815.0	389.0	815.0	5.6
Denmark	1.9	312.0	190.0	553.0	264.0	553.0	3.8
Germany Fed. Rep.	29.1	4,772.0	2,910.0	8,468.0	4,045.0	8,468.0	57.8
Ireland	0.4	66.0	40.0	116.0	56.0	116.0	0.8
Italy	6.9	1,132.0	690.0	2,008.0	959.0	2,008.0	13.7
Netherlands	1.0	164.0	100.0	291.0	139.0	291.0	2.0
United Kingdom	3.7	607.0	370.0	1,077.0	514.0	1,077.0	7.3
Austria	12.6	2,066.0	1,260.0	3,667.0	1,751.0	3,667.0	25.0
Switzerland	4.0	656.0	400.0	1,164.0	556.0	1,164.0	7.9
Greece	2.8	459.0	280.0	815.0	389.0	815.0	5.6
Spain	12.4	2,034.0	1,240.0	3,608.0	1,724.0	3,608.0	24.6
Turkey	38.9	6,380.0	3,890.0	11,320.0	5,407.0	11,320.0	77.2
Australia	13.5	2,214.0	1,350.0	3,929.0	1,876.0	3,929.0	26.8
Canada	138.0	22,780.0	13,890.0	40,420.0	19,307.0	40,420.0	275.7
New Zealand	9.2	1,509.0	920.0	2,677.0	1,279.0	2,677.0	18.3
United States	333.8	54,743.0	33,380.0	97,136.0	46,398.0	97,136.0	662.6
Japan	38.9	6,380.0	3,890.0	11,320.0	5,407.0	11,320.0	77.2

x Luxembourg included

Table 11: Stem Volume and Total Biomass of Growing Stock and Proportional Values of Removals against Stem Volume

Country	Growing stock, M m^3, ob			Removals/ Growing stock, %			Total biomass of growing stock,
	Total	C	NC	Total	C	NC	M m^3 ob
Finland	1,520.0	1,254.0	226.0	2.5	2.3	3.5	2,386.0
Norway	563.0	451.0	112.0	1.5	1.7	0.6	884.0
Sweden	2,288.0	1,966.0	322.0	2.5	2.5	2.1	3,592.0
Belgium	71.0	40.0	31.0	3.2[x]	3.8[x]	2.9[x]	111.0
Denmark	45.0	22.0	23.0	4.2	5.0	3.5	71.0
Germany Fed. Rep.	1,022.0	722.0	300.0	2.8	2.8	2.9	1,605.0
Ireland	15.0	13.0	2.0	2.7	3.1	-	24.0
Italy	286.0	114.0	172.0	2.4	1.1	3.3	449.0
Luxembourg	13.0	2.0	11.0	-	-	-	20.0
Netherlands	20.0	16.0	4.0	5.0	4.4	7.5	31.0
United Kingdom	121.0	68.0	53.0	3.1	3.5	2.5	190.0
Austria	681.0	580.0	101.0	1.9	1.8	2.1	1,069.0
Switzerland	270.0	186.0	84.0	1.5	1.6	1.4	424.0
Greece	134.0	79.0	55.0	2.1	0.9	3.8	210.0
Spain	436.0	259.0	177.0	2.8	2.9	2.8	685.0
Turkey	836.0	549.0	287.0	4.7	2.1	9.4	1,313.0
Australia	1,239.0	109.0	1,130.0	1.1	2.7	0.9	1,945.0
Canada	22,170.0	17,580.0	4,590.0	0.6	0.7	0.3	34,806.0
New Zealand	311.0	296.0	15.0	3.0	2.9	4.7	488.0
United States	20,135.0	12,908.0	7,227.0	1.7	1.9	1.1	31,612.0
Japan	2,186.0	1,215.0	971.0	1.8	1.9	1.7	3,432.0

[x] Luxembourg included

Table 12: Unharvested Forest Biomass in IEA Countries

Country	Gross annual increment of roundwood/year	Gross annual increment of total biomass/year	Removed volume average in 1971-1979 (roundwood)	Gross annual increment of biomass - average anual removals in 1971-1979
	M cum o.b.	M cum	M cum o.b.	M cum.
Finland	57.4	84.7	43.4	41.3
Norway	18.0	26.5	9.6	16.9
Sweden	70.3	103.4	63.9	39.5
Belgium[a]	2.7	4.0	3.1	0.9
Denmark	2.4	3.5	2.1	1.4
Germany Fed. Rep.	37.8	55.8	32.7	23.1
Ireland	1.9	2.8	0.5	2.3
Italy	14.2	21.0	7.8	13.2
Luxembourg	-	-	-	-
Netherlands	1.3	1.9	1.1	0.8
United Kingdom	5.9	8.8	4.2	4.6
Austria	17.3	25.6	14.2	6.5
Switzerland	5.2	7.7	4.6	1.8
Greece	4.4	6.4	3.1	3.3
Spain	31.3	46.2	13.9	35.6
Turkey	22.7	33.5	43.8	-10.3
Australia	30.4	44.8	15.2	29.6
Canada	393.6	580.5	156.2	423.4
New Zealand	11.2	16.6	10.3	6.3
United States	725.0	1,069.0	375.4	693.6
Japan	83.8	123.6	43.8	79.8

[a] included Luxembourg

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POOR

QUALITY

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